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EDXRF with an Audio Digitizer

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Abstract

We utilized an audio digitizer in EDXRF with a silicon drift detector, and achieved a full width at half maximum (FWHM) of 178 eV at Mn K α (92 μ s peaking time). To confirm the ability of EDXRF with an audio digitizer, energy versus channel number linearity and output count rate were also examined. We applied it to EDXRF analysis of (ZnCd)S:Ag and showed a proper energy versus channel number linearity from 5.9 keV (Mn K α) to 26.1 keV (Cd K β). And the maximum output count rate more than 10 kcps was obtained with 23 μ s peaking time (296 eV FWHM).

Introduction

In the previous work, we demonstrated X-ray spectrometer could be comprised of a microphone audio digitizer [1]. We accomplished an X-ray analysis of X-ray from checking source of Geiger-Müller counter with the spectrometer, and showed the capability of the audio digitizer as an A/D converter for X-ray signal processing.

Conventional digital signal processors (DSP) consist of two components, i.e. digitizer and signal processor. Analogue input signals from the detector-preamplifier system are digitized by an A/D converter. Then the DSP generates spectra using hardware based signal processor (i.e. Field-Programmable Gate Array (FPGA) or Application Specific Integrated Circuit (ASIC)). These spectra are sent to a computer and stored for further analysis [2].

The present system also consists of two components. The audio digitizer is used instead of the spectroscopy digitizers in conventional DSP. Then the digitized signals are sent to the computer where the software performs entire signal processing. The digitized time series data are stored in the

computer storage so that they can be analyzed later with different parameters or algorithms.

In this paper, the method outlined in the previous work is applied to the energy range of normal EDXRF, i.e., energy range of about 2 to 25 keV, within which most EDXRF applications are carried on. This is completed by modifications of the software and the experimental conditions from our previous measurement [1]. This will prove a software analyzer and an audio digitizer worked perfectly as a DSP in normal EDXRF energy range consequently. However, its application is limited to the low count rate experiment (up to about 10 kcps) because of the low sampling frequency of audio digitizers.

The microphone digitizer used in the previous work [1] had not been electromagnetically shielded from high-frequency circuit noise from the main board of the notebook computer. And, it was resulted in so poor energy resolution that it cannot be applied to the normal EDXRF. To conquer this problem, we utilized the electromagnetically shielded audio interface, instead of the built-in microphone digitizer, and reduced the circuit noise from the computer main board. FIG. 1 shows the photograph of the practical EDXRF measurement setup. The output signal elicited from an SDD preamplifier is digitized directly by an audio interface and sent to a notebook computer for further analysis by software.

Experimental

An SDD with a preamplifier was used for EDXRF. SDDs have shown better energy resolution than other semiconductor X-ray detectors. The output signals of the preamplifier were analyzed by software on a notebook computer after being digitized by an audio digitizer. In the present work, an electromagnetically shielded audio digitizer was used for signal digitization to reduce the circuit noise; in the previous work, we used an audio digitizer without electromagnetic shield [1].

Our software analyzer was modified to accept signals of up to 32-bit/sample (the previous one accepted signals of up to 16-bit/sample) and signals of the sampling frequency of up to 4 GHz

(usually limited to lower frequency by the digitizer or computer specifications).

We modified the signal shaping algorithm from 1st derivative (unipolar) to 2nd derivative (bipolar) to decrease the effect of baseline shifts. The pulse height was computed from the height: from the local minimum to the local maximum.

Results and Discussion

I. Energy versus channel number Linearity

The energy versus channel number linearity is essential to confirm the new measurement method. To reveal this correlation, we conducted an EDXRF analysis of (ZnCd)S:Ag with the present experimental setup. And we also used the data from the EDXRF spectrum of MnCO₃ (FIG. 4B). Cd K lines are on the edge of the detection efficiency curve. In figure 2, the EDXRF spectrum of (ZnCd)S:Ag shows the spectrum (the upper figure) and the energy versus channel number linearity plot (the lower figure) using the two spectra (EDXRF spectra of MnCO₃ and (ZnCd)S:Ag). This linear calibration of the energy versus channel number was obtained using the K X-ray peaks of Mn, Zn, Ag and Cd.

II. Throughput rate measurement

To investigate the effect of increasing input count rate, an acrylic resin was employed to scatter the incident X-ray to the detector and the tube current increased from 0.1 μ A to 9.6 μ A. A series of analyses were conducted at tube voltage of 35 kV. The graphs of the output count rate versus X-ray tube current are shown in figure 3 for peaking times of 23 μ s, 46 μ s and 92 μ s. At the optimum resolution performance (FWHM of 178 eV at Mn K α) achieved with the 92 μ s peaking time, an output count rate of 2600 counts/s (30 % dead time) could be obtained. With shorter peaking times, 5000 counts/s (30 % dead time, 46 μ s and 187 eV FWHM), and 10000 counts/s (30 % dead time, 23 μ s and 296 eV FWHM) could be achieved.

III. Energy Resolution

Figure 4 shows the comparison of two EDXRF spectra of MnCO_3 . As seen in spectra of Figure 4, the energy resolution was greatly improved in the present result, instead of the equivalence of the two audio digitizers in specifications (see figure caption). FIG. 4A and 4B are spectra obtained by the previous experimental condition [1] and by the present experimental condition, respectively. The only difference between 4A and 4B was digitizer, the built-in microphone digitizer for 4A and USB connected audio interface for 4B. We achieved a full width at half maximum of 178 eV at Mn $K\alpha$ with peaking time of 92 μs . Therefore our proposal that EDXRF method with the audio digitizers is applicable to normal EDXRF measurements.

The measurements indicate the applicability of an audio digitizer by software to the normal EDXRF measurement. The major limitation observed with the spectrometry performance of the present method is its output count rate due to the low sampling frequency and related long peaking time. However, in low count rate X-ray spectrometry measurement (up to 10 kcps) the audio digitizers have enough energy resolution as well as its easy application.

Conclusion

We conclude that an audio digitizer is applicable to X-ray spectroscopy in normal EDXRF energy range instead of an ADC and a DSP. FWHM at Mn $K\alpha$ X-ray measured by audio recording achieved 178 eV (92 μs peaking time). EDXRF analysis of $(\text{ZnCd})\text{S}:\text{Ag}$ were performed to confirm the energy versus channel number linearity and showed a proper linearity in the range of 5.9 keV (Mn $K\alpha$) to 26.1 keV (Cd $K\beta$). Useful output count rate of 2.6 kcps were achieved with 92 μs peaking time (178 eV FWHM at Mn $K\alpha$) and 5 kcps were achieved with 23 μs peaking time (296 eV FWHM). These experimental data confirms the capability of software analyzer with audio digitizer to be used as a digital signal processor of X-ray detectors.

In this report it is just shown that an audio digitizer is operated with our software analyzer as an

ordinary EDXRF analyzer. Without the ambient noise source, energy resolution in EDXRF was improved well. Additionally, recent development of smart phones will allow us to develop versatile handy mobile analyzers in hand.

References

- [1] Y. Nakaye and J. Kawai, X-ray Spectrom. **39**, 318-320 (2010).
- [2] T. Lakatos, Nucl. Instrum. Meth. **B47**, 307-310 (1990).

Figure captions

FIG. 1: A photograph of the practical EDXRF measurement setup. An audio interface was used to decrease the circuit noise from the computer main board.

FIG. 2: (upper) An EDXRF spectrum of (ZnCd)S:Ag phosphor powder. (lower) A plot of energy versus channel number calibration obtained by using K X-ray peaks of Mn, Zn, Ag and Cd.

FIG. 3: Output count rate versus X-ray tube current (as an input count rate) for three different time constants for an audio digitizer and signal processing software. The points denote actual experimental measurements. The solid line represents the ideal response to full counting (no counting loss).

FIG. 4: A comparison of two EDXRF spectra of MnCO_3 measured with (A) the previous experimental condition and (B) the present experimental condition; with a silicon drift detector, a full width at half maximum of less than 180 eV was achieved with an audio digitizer (24-bit 192 kS/s).

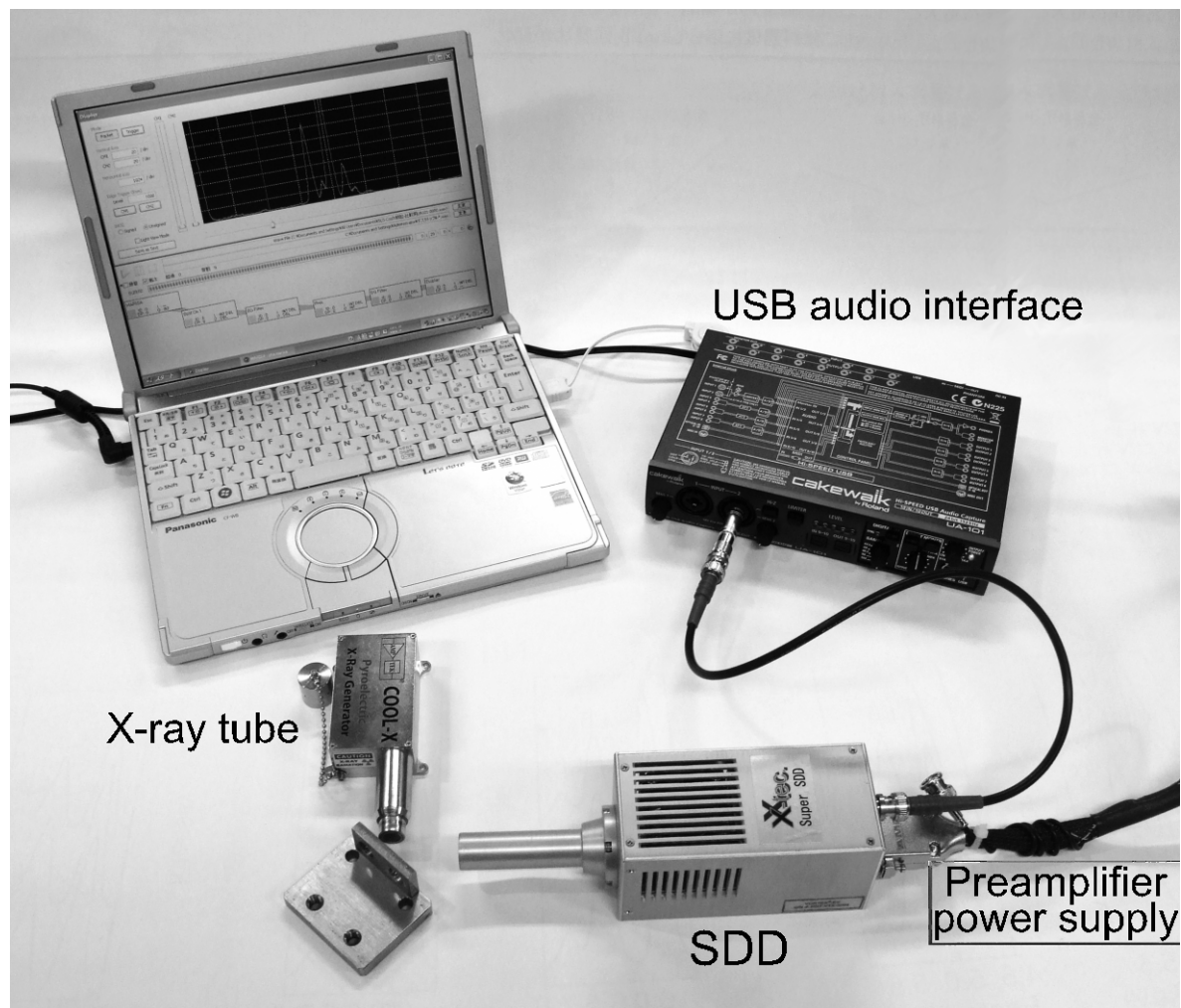


FIG. 1

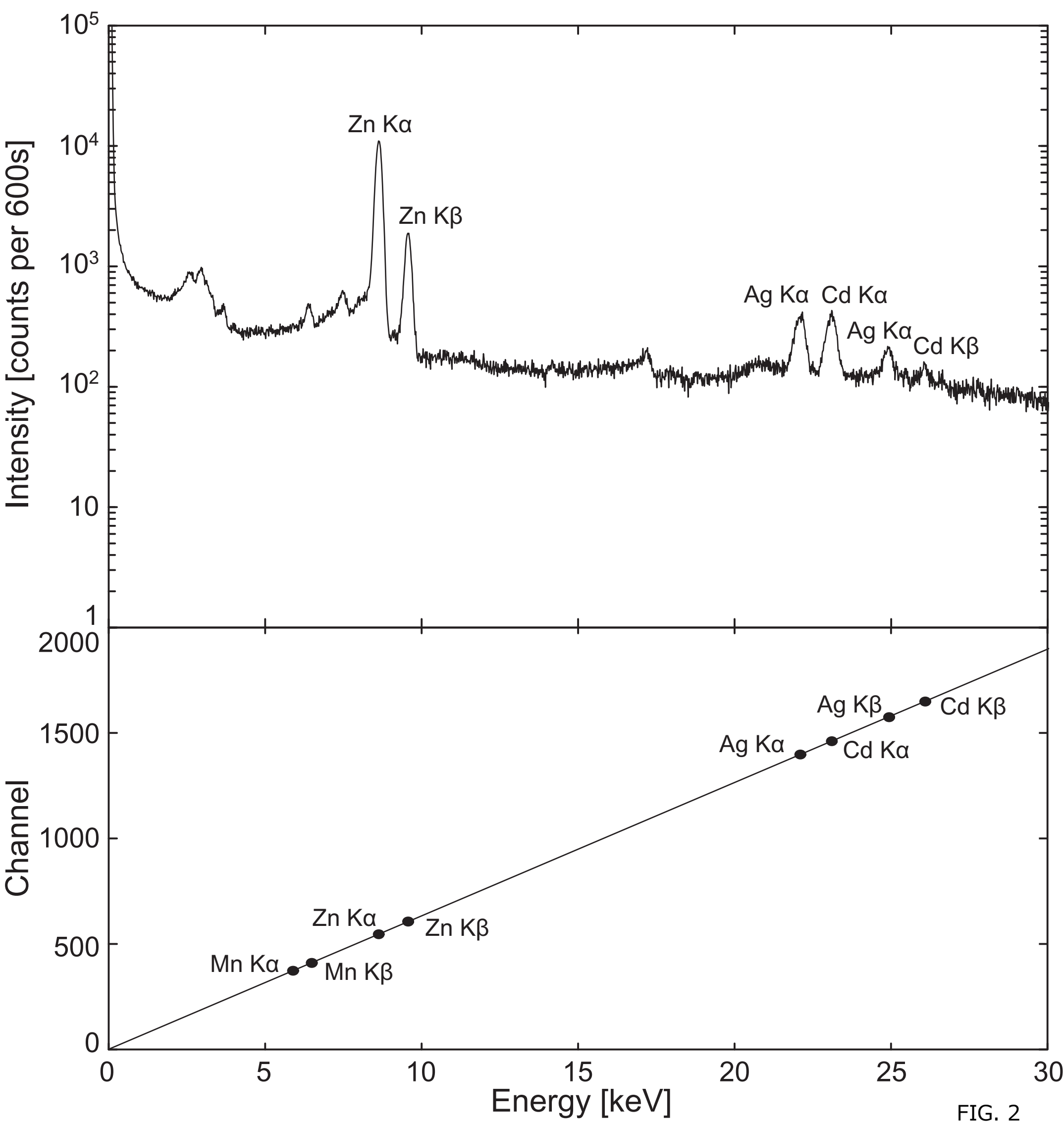


FIG. 2

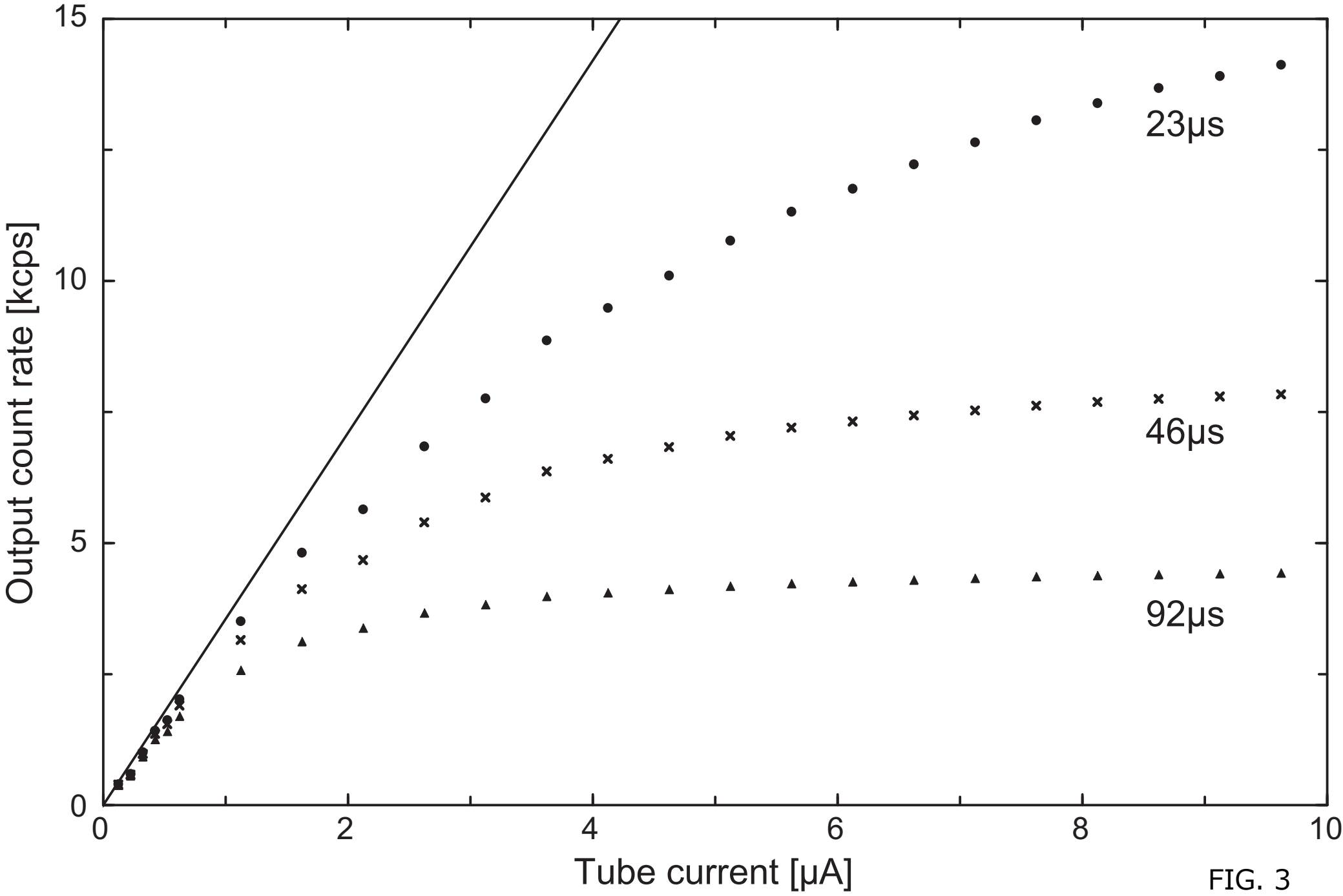


FIG. 3

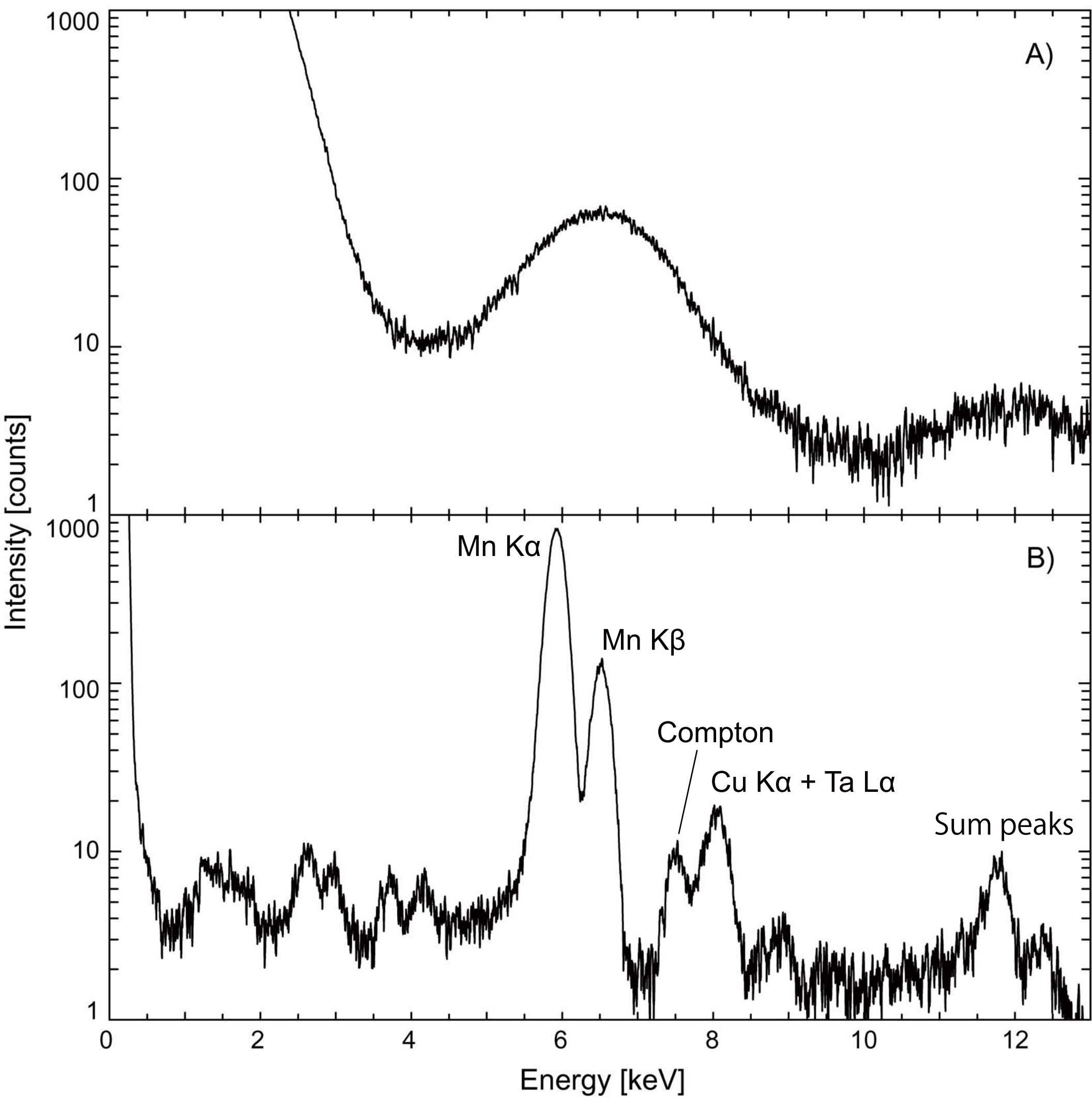


FIG. 4